NC Department of Insurance
Office of the State Fire Marshal - Engineering Division
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Prescriptive placement of insulation-monolithic slab foundation

Code: NC Energy Code **Date:** Feb. 17, 2021
Section: C402.2.5

Question:
Does the slab edge insulation placement[i] shown in Figure 1 perform equivalently to the image in Figure 2, therefore meeting the prescriptive code requirements of Table C402.1.3 or Table C402.1.4?

Figure 1: Illustration of Non-Prescriptive Slab Edge Insulation Placement

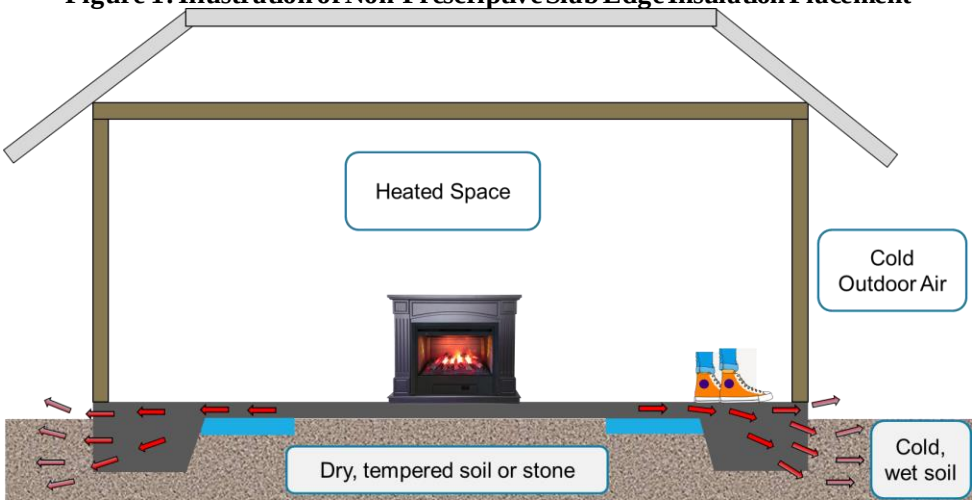
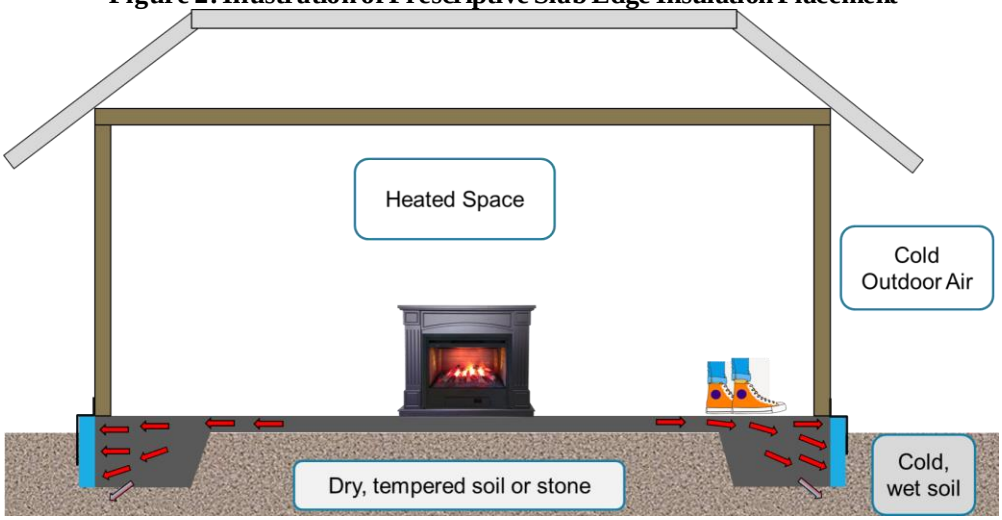


Figure 2: Illustration of Prescriptive Slab Edge Insulation Placement



Answer:
No.

In order to meet the prescriptive code language for slab-on-grade insulation for a monolithic slab foundation, the insulation needs to be placed as illustrated in Figure 2.

The **placement** of slab on-grade floor insulation is very important to minimize heat transfer. The slab insulation for a monolithic slab foundation needs to provide a barrier between the interface where the greatest temperature difference occurs between the interior space and the exterior. That interface is the exterior edge. Although there is heat transfer to the space directly below the building, the bulk of it is to the perimeter, because it is in contact with the soil that sees the greatest amount of daily and seasonal temperature and moisture variation. Although it is easier to visualize heat transfer in the winter months, the summer sun beating on the ground and exterior of the building around the perimeter is also the reason the perimeter placement is key.

Follow-up Question #1:
If the designer wishes to attempt trade-off calculations, where are industry-accepted values for F-factors of various placements and R-values of slab-on-grade floor insulation?

Answer:
In ASHRAE 90.1 Appendix A[ii].

The ASHRAE 90.1 standard, Appendix A, (www.ASHRAE.org) has the F-factors for various slab configurations. Unlike walls, the heat flow from slabs to surrounding dirt is complex, and there is no easy calculation to determine F-factors for configurations not shown in the table. The NC Energy Code, Table C402.1.4, Footnotes **a** and **e** are encouraging users to reference and use this appendix as a resource. These footnotes are reprinted next for convenience.

> a. Use of opaque assembly U-factors, C-factors, and F-factors from ANSI/ ASHRAE/IESNA 90.1 Appendix A shall be permitted, provided the construction, excluding the cladding system on walls, complies with the appropriate construction details from ANSI/ASHRAE/IESNA 90.1 Appendix A.
> e. Evidence of compliance with the F-factors indicated in the table for heated slabs shall be demonstrated by the application of the unheated slab F-factors and R-values derived from ASHRAE 90.1 Appendix A.

The ASHRAE Table referenced herein has explanatory language that accompanies Table A6.3.1 and proper use of the table requires the reading and understanding of said language. In Table 1, a partial reprint of F-factors is shown. The explanatory language describes the difference between horizontal and vertical placement. Similarly, the article referenced in the **Background articles for further reading** section, has illustrations for the reader to research their assumptions regarding insulation placement and how it correlates to Table A6.3.1.

Table 1: Partial ASHRAE 90.1-2016[iii] Table A6.3.1

F-factors (Btu/hr-linear foot-°F) - Unheated Slab (Partial Table)									
	Rated R-value of Insulation								
Insulation Description	**R-0**	**R-5**	**R-7.5**	**R-10**	**R-15**	**R-20**	**R-25**	**R-30**	**R-35**
None	0.73								
12 in. horizontal		0.72	0.71	0.71	0.71				
24 in. horizontal		0.7	0.7	0.7	0.69				
36 in. horizontal		0.68	0.67	0.66	0.66				
48 in. horizontal		0.67	0.65	0.64	0.63				
12 in. vertical		0.61	0.6	0.58	0.57	0.567	0.565	0.564	
24 in. vertical		0.58	0.56	0.54	0.52	0.51	0.505	0.502	
36 in, vertical		0.56	0.53	0.51	0.48	0.472	0.464	0.46	
48 in. vertical		0.54	0.51	0.48	0.45	0.434	0.424	0.419	
Fully Insulated Slab		0.46	0.41	0.36	0.3	0.261	0.233	0.213	0.198
Assumed soil conductivity - 0.75 Btu/hr-linear foot-F									

Illustrated in Table 2 are selected values for reference. Of note, in a commercial building, 0.73 Btu/linear ft-°F corresponds to no insulation[iv]. This amount of heat transfer takes place between the slab and the soil. For comparison sake, 24-inches of R-15 insulation laid horizontally has an F-factor of 0.69 Btu/linear ft-°F, or stated another way this R-15 horizontal placement of insulation allows 94.5% of the heat transfer that zero insulation allows. That is not accomplishing much. However, 24-inches of R-15 insulation placed vertically at the edge of the slab has an F-factor of 0.52 Btu/linear ft-°F, which only allows 71.2% of the heat transfer as zero insulation.

This should also help illustrate why it can be difficult to do trade-offs if slab insulation is omitted or installed in non-prescriptive ways, because it simply does not reduce the heat transfer appreciably and this then must be made up in other areas of the building that are already fairly well insulated. Everyone is familiar with the concept of diminishing returns when additional inches of insulation are added, but that concept cuts both ways, and when you go from only one or two inches down to zero, that heat transfer rapidly increases.

Table 2: Selected F-factors for comparison

F-factors (Btu/hr-linear foot-°F) - Unheated Slab (Partial Table)										
	Rated R-value of Insulation									
Insulation Description	**R-0**	**R-5**	**R-7.5**	**R-10**	**R-15**	**R-20**	**R-25**	**R-30**	**R-35**	
None	0.73									No insulation
12 in. horizontal		0.72	0.71	0.71	0.71					
24 in. horizontal		0.7	0.7	0.7	0.69					Commonly misused insulation placement
36 in. horizontal		0.68	0.67	0.66	0.66					
48 in. horizontal		0.67	0.65	0.64	0.63					
12 in. vertical		0.61	0.6	0.58	0.57	0.567	0.565	0.564		
24 in. vertical		0.58	0.56	0.54	0.52	0.51	0.505	0.502		Zone 4 Prescriptive
36 in, vertical		0.56	0.53	0.51	0.48	0.472	0.464	0.46		
48 in. vertical		0.54	0.51	0.48	0.45	0.434	0.424	0.419		
Fully Insulated Slab		0.46	0.41	0.36	0.3	0.261	0.233	0.213	0.198	
Assumed soil conductivity - 0.75 Btu/hr-linear foot-F										

Background articles for further reading:

A technical document that provided F-factor values for some of the configurations shown in the ASHRAE Appendix A is available at the following website for reading and comparison:

https://ecotope-publications-database.ecotope.com/1991_012_SuperGoodCentsHeat-V4.pdf[v]

As discussed in the article in the preceding link, the values for the F-factors were developed from in-situ measurements under various field conditions. Also discussed, is the F-factor is a simplified value that was developed in order to have a value that has the same units of measure (Btu/h-F) in order to allow trade-offs with other building components. This is no easy task, and the simplified F-factor value may certainly underestimate heat transfer during times of the year if soil conditions are wetter than the average assumed value.

If one wishes to research an important reference for slab insulation F-factors for Residential buildings covered in the NC Residential Code, the reader can search on "OT-88-02-2 -- WHOLE-HOUSE SIMULATION OF FOUNDATION HEAT FLOWS USING THE DOE-2.1C PROGRAM" and various sites will have it. This study is cited by the ResCheck technical document for its source of slab F-factors.

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[i] These are diagrammatic drawings. They are not to scale and are not intended for use as construction details. Construction-quality details are available from various manufacturers and design professional firms, that fully illustrate and integrate the walls and the slab and best practices for water, air, and thermal management.

[ii] There are also many other commercial building elements, such as walls, floors, roofs, and roof/ceiling combinations covered in this Appendix.

[iii] There are various versions of ASHRAE 90.1 available for review, the version cited in NC Energy Code is the 2013 version, but both the 2016 and 2019 versions are available for review and use pertaining to their use as a technical resource.

[iv] This value is valid for commercial buildings represented in the ASHRAE 90.1 standard or the NC Energy Conservation Code-2018. The slab F-factors for buildings governed by the Residential Code follow a slightly different in-situ study, and the value for no insulation is 1.043 Btu/linear-ft-F and 1.041 Btu/linear-ft-F for a 2-ft and 4-ft depth, respectively.

[v] This study is available in several different edited versions on the Internet. Although it was originally cited as for Residential buildings, it is used for commercial buildings, perhaps because of the 6-inch concrete slab used in the study is more common with commercial buildings. Thanks to Mr.Ben Edwards of Mathis Consulting for the reference to this document.